UDC 666.643.5:666.032.4

EFFECT OF THE PHYSICAL PROPERTIES OF SLIP ON THE MOLDING OF COMMERCIAL GRADE SANITARY WARE

V. V. Mikhalev,[1] V. V. Serov,[1] and A. S. Vlasov[1]

Translated from *Steklo i Keramika*, No. 4, pp. 21 – 22, April, 2007.

The use of a method of determining the densification factor and the interparticle distance for commercial grade ceramic slips is demonstrated. Elevated viscosity and structure-formation rate give high densification factors. A method of determining the physical parameters of slips from granularity data makes it possible to evaluate the filtration properties of slips for casting commercial grade sanitary ware.

Construction is undergoing intense growth, creating demand for greater production of materials and articles, including sanitary ware.

Slip casting as the principal method of molding sanitary-wear ceramic is one of the most complex stages in the technological process. Almost all quality determining processes, the number of defects, and the external appearance of the articles obtained occur at the stages of slip preparation and article formation. In the slip-casting process special attention must be devoted to the mechanisms of structure formation, including the appearance of electric double layers on the surfaces of clay particles and adsorption layered aggregates, the transition of water from the liquid state into a loosely bound state, and the adsorption of molecules of polyelectrolytic additives. Controlling these stages of structure formation makes it is possible to influence the parameters of the ceramic mass during formation, drying, and calcination and, ultimately, the quality of ceramic articles.

Since clays and kaolins are the principal forms of the raw materials used for the production of sanitary ware, their composition, structure, and ratio in the ceramic paste will determine its behavior when mixing with water and during the formation of an article. Clays and kaolins differing by the content of minerals such as kaolinite, montmorillonite, and hydromica and the presence of silica sand grains with different sizes and shapes make it possible to obtain the optimal batch composition guaranteeing defect-free nonporous articles.

At the present time pressure casting in polymer molds is the most promising method for producing commercial grade sanitary ware. This method is technologically efficient, but it has a number of drawbacks — high cost of complex equipment and energy carriers and high cost of the molds, which are produced in only small numbers. Consequently, it is still important to improve the traditional method of slip casting in a gypsum mold.

When determining the physical and chemical properties of powders, measurements of the rheological properties of a suspension comprise the final assessment. The rheological properties cannot be used to control the technological process after the mixture has been prepared, but they make it possible to predict the properties of the slip if the interparticle interactions are correctly taken into account and regulated.

The objective of the present work is to assess the effect of the slip composition on the technological properties of the paste in order to find the optimal composition determining the quality of articles and to determine the parameters affecting the casting, molding, filtration, and other technological properties of ceramic slips.

A method of determining the physical parameters of slip, such as the densification factor and the interparticle distance, from the granularity data was used. The American scientists J. Funk and D. Dinger proposed this method [1]. It was developed to calculate the parameters using a theoretical particle-size distribution curve. In the present work this method was used to find the parameters of the pastes prepared at the "Kirovskii stroifarfor" CJSC.

Three ceramic pastes were used in this work: the standard paste S-1 and two experimental pastes — A-1 and F-1. Clays and kaolins obtained from the principal deposits and widely used in the commercial production of sanitary ware ceramic were introduced into the pastes. A great deal of attention was devoted to the granularity of the pastes studied, which was determined with a sedigraph.

[1] "Kirovskii stroifarfor" CJSC, Kirov, Russia; D. I. Mendeleev Russian Chemical Engineering University, Moscow, Russia.

0361-7610/07/0304-0129

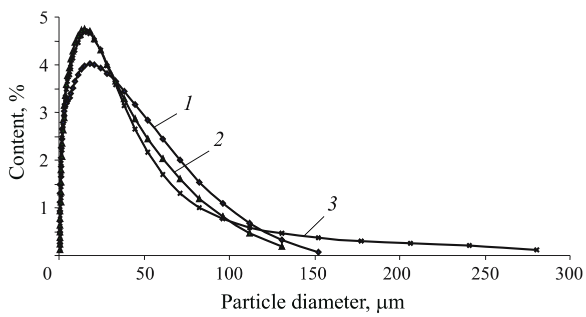

Fig. 1. Granularity of the pastes A-1 (*1*), F-1 (*2*), and S-1 (*3*).

Several assumptions must be made about the measurement procedure. One assumption is that the particles are spherical. In reality the shape of the particles in the slip is far from being spherical, since the plastic component consists of layers of flat clay particles. Therefore, the results of this measurement cannot be absolute; they can be used only for comparing pastes with different composition, assuming an effective value for calculating the particle sizes. The measurement was performed using ultrasound to break up aggregates. This method makes it possible to break up only the coagulation aggregates keeping the adsorption aggregates intact so that the effective diameter is overestimated. The granularity of the experimental pastes is presented in Fig. 1.

The physical parameters of the slips were calculated using grain composition data: the densification factor, the interparticle distance, and the specific volume of the capillary pores.

The densification factor (the concentration of particles in 1 cm^3 of slip) is found for each particle fraction. Knowing the volume of the each fraction and the average size of the particles, the number of particles of a given fraction in the volume can be determined. The values obtained for all fractions were summed and the total densification factor was found. The A-1 slip had the highest densification factor.

As the particle concentration in the volume increases, the overlapping electric double layers of adjacent particles are compressed. This increases the repulsive forces, the viscosity, the outflow time of the slip (not only because the number of particles increases but also because the viscosity of the water itself present in the interparticle space increases), the rate of structure formation, the yield point, and the plasticity [2].

TABLE 1.

Indicator*	Slip		
	A-1	F-1	S-1
Specific surface area, m^2/m^3	1.713	1.350	1.339
Densification factor, $K \times 10^{-11}$	8.50	4.74	3.59
Volume fraction of porous channels in the slip, %	0.25	0.14	0.13
Interparticle distance, nm	395	609	682

* The shortest particle diameter was 0.31 μm in all cases.

One of the most important consequences of an increase of the particle concentration is that the rate of structure formation increases. As paste is added to the gypsum mold, a three-dimensional fishing-net structure is formed in the slip. In [3] it was established that the faces and edges of the plate-shaped clay particles are oppositely charged — the edges positively and the faces negatively. The electrostatic forces form a reticular structure which has a high filtration rate. Therefore, a high rate of mass accumulation is observed in slip with the highest densification factor even though this slip has the highest viscosity, which strongly affects the production rate in bench casting.

Another parameter that affects the rate of structure formation is the average interparticle distance, given by the relation

$$\frac{L}{2} = \frac{1}{S_V}\left(\frac{1}{V_S} - \frac{1}{1-P_v}\right),$$

where L is the interparticle distance, nm; S_V is the specific surface area per unit volume, m^2/m^3; V_S is the volume fraction of the solid phase of the slip; and P_v is the volume fraction of porous channels in the slip (found from the granularity data).

The interparticle distance could be the most important parameter, since if it remains constant when the apparent density of the slip changes as a result of a change in the physical parameters of the particles, the effect of these changes on the physical and chemical properties of the particles will affect the rheological properties most strongly. The results obtained are presented in Table 1.

Data obtained at "Kirovskii stroifarfor" CJSC show that the A-l slip accumulates mass three times more rapidly than the S-1 slip. This means that the cast forms in 40 min for the A-1 slip and 120 min for the standard S-1 slip. The rate of mass accumulation for the F-1 slip is 80 min.

The data obtained here also confirm this — the densification factor of the A-1 slip is two times greater than that of the other two slips and the volume fraction of porous channels is two times higher with the shortest distance between particles (395 nm). Larger interparticle distances and lower values of the densification factor give a lower rate of structure formation in S-1 and F-1 slips. The F-1 paste has more satisfactory indicators and is also suitable for the technological process.

In summary, the larger the densification factor is, the more particles participating in the formation of the cast structure, the higher the casting rate, and the more moisture retained in the cast. The more moisture retained in the cast, the more open the three-dimensional structure is and the faster the casting process itself and the faster the drying are. In addition, the article can remain in the mold for a longer period

of time without any danger of cracking, and the improved plasticity will make it possible to avoid difficulties when working the articles. The drop of the moisture content along the casting wall will be lower because of the higher porosity of the structure, so that the shrinkage stresses and cracking during drying will be diminished.

The method of determining the physical parameters of slip pastes from granulometric data makes it possible to estimate the filtration properties of a slip paste during casting of sanitary-ware articles.

Production experience shows that pastes which allow a cast to form in 40 – 60 min will permit two castings during one 8-h work shift. This will increase the productivity of labor by 80 – 100%.

REFERENCES

1. J. E. Funk and D. R. Dinger, "Slip control using particle size analysis and specific surface area," *Am. Ceram. Soc. Bull.*, **67**(5), 890 – 894 (1988).
2. J. E. Funk and D. R. Dinger, "Modeling the slip casting processes," *Ceram. Eng. Sci. Proc.: Am. Ceram. Soc.*, **11**(3 – 4), 217 – 227 (1990).
3. J. S. Reed, *Introduction to the Principles of Ceramic Processing*, New York (1988).